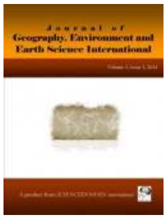

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# Geo-Spatial Mapping of Air Pollution in Benin City, Nigeria

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***Authors' contributions***

*The study was conceived and designed by the both authors. Author VSB was responsible for the fieldwork, air quality survey, data analysis and wrote the protocol. Author OOIO supervised the whole work from draft to final execution and responsible for the editing of the manuscript. Both authors read and approved the final manuscript.*

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## ABSTRACT

The study investigates the distribution and mapping of air pollutants in Benin City using land use and administrative maps, a Global Positioning System (GPS) device, Geographic Information System (GIS) techniques and field sampling. Air sampling for the study covered a period of six months, between mid-October 2013 and mid-April 2014. Air pollutants of concern included particulate matter ($PM_{0.3,\ 0.5,\ 1.0,\ 2.5,\ 5.0\ \text{and}\ 10\ \mu m}$) and carbon monoxide (CO). Particulate matter was measured using a hand-held particle counter, while CO was measured with a single gas monitor (T40 Rattler). Five sampling points, coordinates of which were determined using the GPS device, were selected based on stratified sampling technique and they represented the five land use types monitored in the study area (i.e. institutional, agricultural, commercial, industrial and residential). Sampling was carried out twice weekly in accordance with the guidelines of Central Pollution Control Board, Delhi India. Sampling height was two meters above ground level. Field data was inputted into a GIS data base from which interpolation and spatial correlation analyses were carried out. The results showed that commercial and industrial areas were characterized by higher

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concentration levels of pollutants, while institutional and agricultural areas were characterized by less of same. The study recommended appropriate actions by town planning authorities in addressing the challenges of air pollution resulting from improper zoning systems, adjacent placement of incompatible land uses, inadequate barricading of high air polluting land uses and non compliance to land use permitting process.

*Keywords: Carbon monoxide; land use; mapping; particulate matter.*

## 1. INTRODUCTION

The atmospheric component of the environment consists of a mixture of gases, which support the life of plants and animals. Under normal circumstances, gaseous components which include Nitrogen, Oxygen, Carbon dioxide and other noble gases, exit in percentage ratios of 78:21:0.4:0.6 respectively. Introduction of contaminants such as $SO_2$, CO, Ozone NOx and Chlorofluorocarbons (CFCs) at toxic levels by land use activities could practically pollute the atmosphere, and in turn impact negatively on the quality of life on the earth. Air pollution has been defined by the World Health Organisation as the 'contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere' [1]. There is a strong conviction among some environmental scholars, stake holders and concerned individuals from different countries of the world, that global warming over the past fifty years is attributable mainly to atmospheric pollution caused by human activities. The analysis of climate research carried out by the Intergovernmental Panel on Climate Change [2] has thrown greater weight on man's activities as the major propellant of global warming. This theory of human caused global warming is an off shoot of enhanced greenhouse effect also caused by humans. Water vapour, carbon dioxide and some other minor gases present in the atmosphere in much smaller quantities absorb some thermal radiation leaving the earth's surface, acting as a partial blanket for this radiation and causing the difference of approximately 21℃ between the actual average surface temperature on earth of about 15℃ and the figure of -6℃ which applies when the atmosphere contains nitrogen and oxygen only. This blanketing is known as the natural greenhouse effect and the gases are known as greenhouse gases [3]. Having greenhouse gases in higher quantities, results in enhanced greenhouse effect, which could also be captioned as global warming. Water vapour, which is one of such greenhouse gases emanate from evaporating water molecules at the ocean surface. The amount of water vapour which originates from ocean surfaces is directly proportion to the temperature of the ocean surface. Thus higher temperatures release more water vapour into the atmosphere. Human activities causing increases in the concentration of carbon dioxide, carbon monoxide and other minor gases, which trap reflected thermal radiation from the earth, would thus impact on the temperature of the ocean surfaces, thereby leading to the release more water vapour and then further global warming. The amount of carbon compounds in the atmosphere has increased substantially (about 30% since the industrial revolution [3]. Future projections are that, in the absence of controlling factors, the rate of increase in atmospheric carbon will accelerate and that its atmospheric concentration will double from its pre-industrial value within the next hundred years. This could result in a global temperature increase of about $2.5^0$C within the next hundred years [3]. The impact of global warming based on the report of the IPCC include migration of both humans and animals because of sea level rise, discomfort and poor health arising from invasion of disease causing agents, decreased fresh water supply, decreased crop yields, salinization of irrigation water and increased risk of extinctions around the globe. In Benin City, strong evidence of global warming as been noted by Atedhoret' al, has shown the rise in mean temperature since the late 1960s, with a corresponding above normal rainfall pattern between 1988 and 2009. The effect of global warming has impacted on the city in terms of flooding and excess water run-off [4].

Nigeria and most developing countries are also susceptible to the impact of growing industrialization and increasing commercial activities on the quality of air especially within the urban centres. According to Ukpebor et al. air borne particulates are the most obvious form of pollution in most Nigerian cities [5]. Studies carried out on air pollution in Lagos the largest city in Nigeria, revealed levels of particulate matter as high as 40,000µgm$^{-3}$ at industrial sites and 1,033 $\mu gm^{-3}$ in ambient air [6-8]. In Benin City, Studies carried out by Ukpebor et al. at five sampling sites revealed that average air borne particulate matter concentration measured using a haze-dust air monitor, ranged from 240 $\mu gm^{-3}$ to 675 $\mu gm^{-3}$ [6]. Mean concentration at four of the sampling sites exceeded the regulatory limits of 250 $\mu gm^{-3}$ [9] and 230 $\mu gm^{-3}$ [10]. The study identified automobile exhaust, solid waste incineration, industrial emission, fugitive dust from roads and harmattan dust as the major causes of high particulate matter concentration. Study on Carbon monoxide pollution in Benin City was carried out by Ukpebor et al. at five sampling points also. High CO concentration (ranging from 14.8ppm to 28.3 ppm) recorded [11], clearly exceeded the regulatory limit of 10.0ppm set by the Federal Ministry of Environment. Diurnal variations were also statistically significant, with the highest CO concentration recorded in the morning hours. The major causes of high CO concentration were attributed to high traffic density, traffic jams and low wind speed.

Generally, in mapping out air pollution in an urban city, it should be pointed out clearly that there are a number of factors which contribute to atmospheric pollution. These include climatic factors such as wind, cyclones, natural fires and tectonic factors such as volcanic eruptions, which pollute the atmosphere with volcanic ashes. These are naturally induced factors, different from man induced factors. Man induced factors result from activities such as industrial processes, automobile transportation, domestic activities (i.e. use of household combustion devices), open burning of wastes, mining etc. Previous research carried out on air quality in Benin and Lagos Cities as reviewed above, involved comparative analyses among air quality readings at market areas, industrial axis and high traffic routes. This study goes further in including residential units and agricultural spaces in a comparative analysis. This provides an all-inclusive air quality studies involving all land use types in Benin City. Benin City is a metropolitan city in south-south Nigeria. Based on meteorological and tectonic records for Benin City, naturally induced factors are highly insignificant, compared with the human induced factors. This has drawn the focus of this research to human activities as the major factor impacting on air quality. The various land use activities in Benin City, surveyed, identified and represented using GIS and land use mapping techniques include commercial (which includes transportation hubs, markets places and ports), industrial, residential, agriculture, and Institutional (administrative and public facilities) land uses.

In this study, the main concern lies in determining what land use activities account for greater pollution in an urban environment, the impact of air polluting land uses on sensitive land uses, as well as health implication arising from such. A comparative assessment places different land use activities in a spectrum, based on average amount of CO and Particulate Matter concentrations measured for different land uses.

## 2. STUDY AREA, MATERIALS AND METHODS

Benin City, the capital of Edo State is located in the South-South geopolitical region of Nigeria. It is bounded by latitude 6°11'N, 6°27'N (Southern and Northern boundaries) and longitude 5°31'E and 5°44'E (Western and Eastern boundaries) and has an estimated land area of 500 square kilometres [12]. The city falls within the tropical equatorial zone characterized by dry and wet seasons, with an estimated annual rainfall of over 2000mm and average temperature of 27°C [13]. Wet season spans between the months of March and October, while the shorter dry season begins in November and ends in February. Generally, rain falls all year round in Benin City with double peak periods in the months of June or July and September, and a short temporal break in August. Benin City has a population of 3,218,332 [14] and comprises four local government areas, which include IkpobaOkha, Oredo, Ovia North East and Egor local government areas.

The primary data includes air quality parameters collected from distributed sampling stations across the study area, coordinate values of which were captured with the use of GPS (Global Positioning System) device, marking sampling stations and other features of interest.

The secondary data includes a 1:50,000 scale topographical map, an administrative map, and Google Earth image extract covering the study area. The extracted Goggle Earth imagery of Benin City was used to update the administrative and study area map. Previous literatures relating to the study were also used as secondary data sources.

Five Sampling points were randomly selected based on the 'neighborhood' method of siting sampling points, as specified in Australian Standard – AS2922 [15]. Each sampling point represented the major type of human activity prevalent in that area. Human activities were categorized into Institutional, Agricultural, Commercial, Industrial and Residential land use activities. Institutional land use comprises structures put up for educational, administrative and health purposes (E.g. University of Benin, University of Benin Teaching Hospital etc.). Agricultural land use comprises lands specifically occupied by farms, gardens and plantations. Commercial land uses include trading stores and outlets, transportation hubs and distribution centres of goods and services. These are mostly located at the central business district (Ring Road) and also along major routes and intersections. Industrial land uses constitute the major industries in Benin City, which include the Guinness Breweries and the Nigerian National Petroleum Corporation. Residential Units comprise buildings which serve as homes where individuals and families retire to at the end of the day. Residential neighbourhoods exist at almost all parts of the city. Table 1 shows the names, locations, coordinates and elevation of the five sampling points chosen for the study as well as the land use type each represents.

The two major pollutants considered include Particulate Matter (PM0.3, PM0.5, PM1.0, PM2.5, PM5 and PM10 µm) and Carbon II Oxide. The light scattering method was applied, by use of a CEM (Continuous Emission Monitor) Particle Counter in detecting and counting air borne particles at a height of two metres from ground level while Carbon II Oxide concentrations were measured using a Single Gas Monitor called the T40 Rattler at the same height. Taking measurement at two meters above ground level provides concentration values of air pollutants at a level at which humans are most likely exposed, while at the same time, preventing interference of fugitive dust from loose soil surfaces with the air quality readings.

Sampling frequency for both Particulate Matter and Carbon II Oxide was carried out twice weekly according to the guidelines of the Central Pollution Control Board, Ministry of Environments and Forests, India [16]. Sampling duration was six (6) months, beginning from mid-October 2013 to mid- April 2014, producing a total of 52 sample counts per sampling point. Total sample counts were 260. Spatial analysis was done applying GIS and non-GIS software packages (ArcGIS, and Excel), which were used to synthesize and integrate both air quality and land use datasets. To delineate the study area, the topographic and administrative map covering the study area were geo-referenced (with Root Mean Square Error - RMSE of 0.00001). Subsequently, the topographic map was placed in an ArcGIS Environment and a map subset derived covering the study area. The subset output from the topographical map, as well as the administrative map were digitized using on-screen method. The digitized topographical and administrative maps were overlaid on each other, while a frame marking out the Region of Interest (ROI) that lies between latitudes 6012'N and 6028'N and longitudes 5030'E and 5047'E was used to mark out (submap) the study area for this study. The spatial mapping process air pollutants involved the use of 'Krigging' technique in creating isoline maps. 'Krigging' is a geo-statistical method of interpolation, for which the interpolated values are modelled by a Gaussian process, governed by prior co-variances. Under suitable assumptions on the prior, krigging gives the best linear unbiased prediction of the intermediate values. This method is widely used in the domain of spatial analysis.

**Table 1. Names and location of sampling points**

| Sampling location | Coordinates | Land use activity prevalent | Elevation (metres) |
|---|---|---|---|
| 1. University of Benin (UNIBEN) | 6023'47.8 N 5037'30.2E | Institutional | 103 |
| 2. PPRH Plantation | 6024'15.3 N 5036'16.1 E | Agricultural | 114 |
| 3. Ring road/Mission road. | 6019'53.1 N 5037'26.5 E | Commercial | 84 |
| 4. Ikpoba Hill/ Benin-Auchi road | 6020'52.4 N 5040'6.6 E | Industrial | 115 |
| 5. Akugbe/ Eweka road. | 6021'36.6 N 5037'55.3 E | Residential | 90 |

## 3. RESULTS AND DISCUSSION

Land uses identified in the study area include institutional, agricultural, commercial, industrial and residential land uses. They have been spatially represented in Fig. 1. The values in Table 2 represent total mean values of air quality parameters ($PM_{0.3\text{-}10\ \mu m}$ and Carbon Monoxide), obtained at the five land use sampling points. These total mean values were derived from the synthesis of bi-weekly readings taken from a Continuous Emission Monitor (CEM) particle counter and a Single Gas Monitor. The CEM particle counter provided concentration values for particle counts $PM_{(0.3,\ 0.5,\ 1.0,\ 2.5,\ 5.0\text{ and }10\ \mu m)}$ for air pumped at the rate of $0.1ft^3 minute^{-1}$ for an averaging period of 10 minutes, while the Single Gas Monitor provided concentration values of CO in PPM, for an averaging period of 15 minutes. The highest total mean values for $PM_{(0.3,\ 0.5\text{ and }1.0)\ \mu m}$ were recorded at sampling point 4 (i.e. Ikpoba Hill/Agbor road, representing industrial land use), while the highest total means for $PM_{(2.5,\ 5.0,\ 10.0)\ \mu m}$ and CO were recorded at sampling point 3 (i.e. Ring road, representing commercial land use). Minimum mean values for $PM_{(0.3\text{ and }0.5)\ \mu m}$ and CO were recorded at sampling point 2 (i.e. PPRH plantation, representing Agricultural land use), while minimum mean values for $PM_{(1.0,\ 2.5,\ 5.0\text{ and }10.0)\ \mu m}$ were recorded at sample point 1 (i.e. the University of Benin, representing Institutional land use).

On seasonal variations, peak mean values for $PM_{(0.3,\ 0.5\text{ and }1.0)\ \mu m}$ were recorded in the dry season month of November, that for $PM_{(2.5,\ 5.0\text{ and }10.0)\ \mu m}$ occurred in the dry season month of February and, that for CO occurred in the dry season month of January. Minimum values for all pollutants occurred in the wet season months of either October or April.

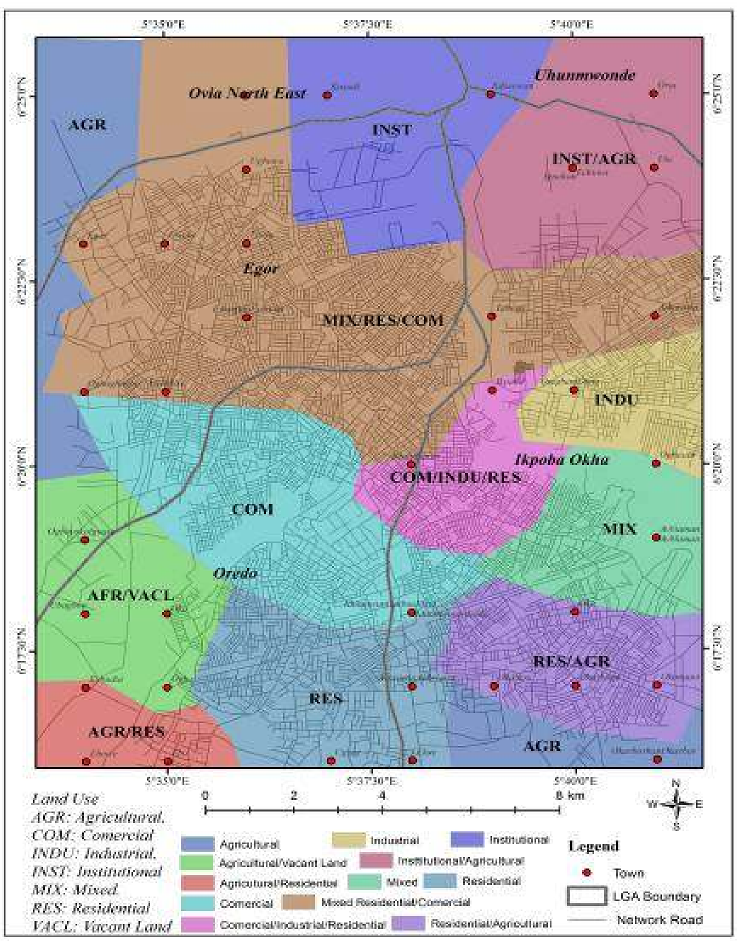


**Fig. 1. Benin City: Spatial spread of land use activities**

*Source: Ministry of Lands, housing and urban development, Edo state; (Updated during field work, 2014)*

Based on the Krigging technique, the Isoline maps presented in Figs. 2–8 show the connections among areas of similar concentration values of pollutants and the demarcation between areas of differing concentration values of pollutants. This is easily interpreted by the use of different shades of hue to represent different concentration values. The spatial analysis reveals higher concentration of pollutants at the commercial city centre, tending westwards towards the local airport and eastwards towards the industrial axis of the city. This is recognisable by the darker hues covering such areas in the map. Less concentration of pollutants occur at the outskirts or suburbs, which consist of institutions, agricultural lands, vacant spaces, and newly developed residential units. They are identifiable by the use of lighter hues in the map.

Based on the graphical representation of spatial spread of pollutants in Figs. 2–8, one can decipher that higher concentration of pollutants at areas around the city centre result from the high and constant influx of human activities, which characterise commercial land use. The centre of the city is a point at which majority of commuters most certainly pass through on a daily basis in the course of carrying out their daily commitments. In addition, the presence of large markets at the city centre, and at areas close to the city centre (e.g. Oba market, New Benin market and Agbado market), attracts a high volume of commercial activities. Both vehicular and human traffic jams are a common sight. Ukpebor et al. have affirmed that regular traffic jams, caused by high traffic density, unfavourable traffic handling and traffic indiscipline are some of the major sources of pollutants in commercial areas [5]. Worthy of note also is the fact that Benin City is a nodal town, connecting North, South-south, East and Western parts of the country. The presence of inter-state commuters is thus a common sight, as most travelling routes which approach the city, converge at the city centre before dispersing to various directions. Residential units, some of which fall within the city centre, Government Residential Areas, Commuting zone and the periphery are mid-way between high pollution and low pollution zones, in terms of pollution concentration.

Pollutants emanating from residential units are mostly the result of the use of non-tar roads, domestic cooking (i.e. the use of stoves, cooking gas, coal and fire wood), electricity generating sets and open burning of solid waste. Also residential units located close to commercial and industrial zones are certainly affected by high pollutant doses emitted by commercial and industrial activities. Less concentration of pollutants characterise the periphery of the city, in which are located government institutions, agricultural lands, new residential developments and vacant lands. Human activities are less concentrated in these areas as well. The presence of gardens and tended trees within and around institutions and plantations play a role in recycling of Carbon, and production of oxygen in the atmosphere. This helps to improve the quality of the atmospheric environment in these areas.

On seasonal variation, pollution levels were generally higher in the dry season, compared with the wet season. The highest monthly means for $PM_{(0.3,\ 0.5,\ 1.0,\ 2.5,\ 5.0\ \text{and}\ 10)\ \mu m}$ were attained in the dry season months of November and February, while that for CO was attained in the dry season month of January. A study by Jacobson has pointed out that higher concentration of pollutants observed during the hot seasons can be explained by higher ambient temperatures, leading to downward movement of pollutants and consequently high ground level concentrations [17]. Jacobson went further to explain that if temperature of pollutant gases (also known as plumes) is higher than the surrounding air, the plumes will tend to rise. On the other hand, if temperature of ambient air is higher, pollutant gases become concentrated at ground level. Atmospheric temperature is thus an important factor for the dispersion of pollutant gases, as the larger the difference between cool ambient air and plumes, the higher the plume rises. The higher the rise of plume, so also is the rate of dispersion or spread of pollutants from its source before it reaches ground level. Relative humidity is another meteorological factor that explains the concentration of pollutants at a point. Relative humidity, which is and inverse function to atmospheric temperature, is generally higher during the wet season. The higher the relative humidity, the less the atmospheric temperature, consequently less the rate of plume ascent, and vice versa. Ukpebor et al. have also asserted that wind speed is also a significant meteorological factor in determining the accumulation, dilution and dispersion of generated pollutants. Wind speed is generally low in Benin City ranging from 0.0 $ms^{-1}$ to 1.5 $ms^{-1}$ [11], therefore dilution, by way of dispersion of pollutants, is minimal year round.

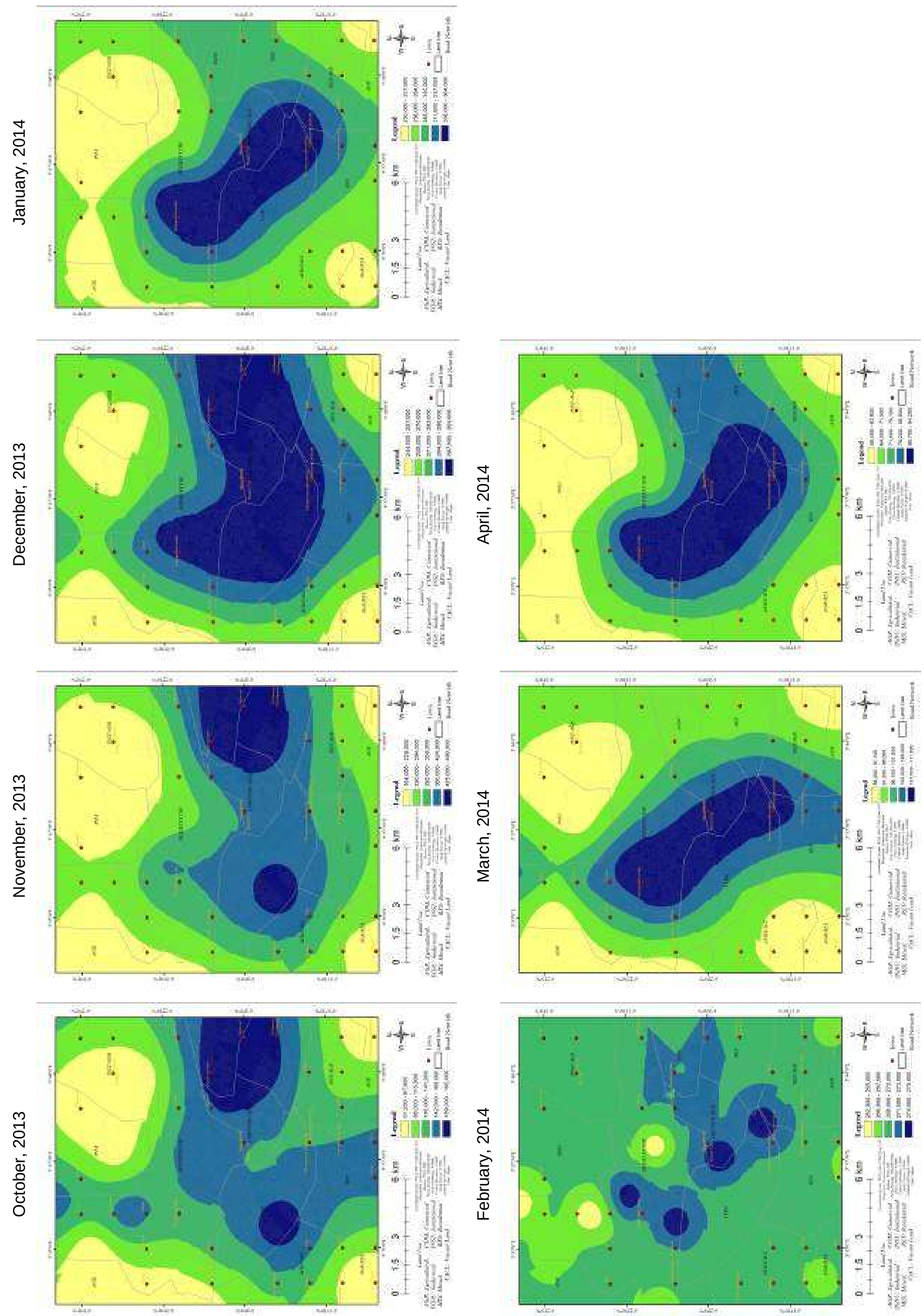


**Fig. 2. Spatial and temporal variations in concentration values of PM0.3µm**

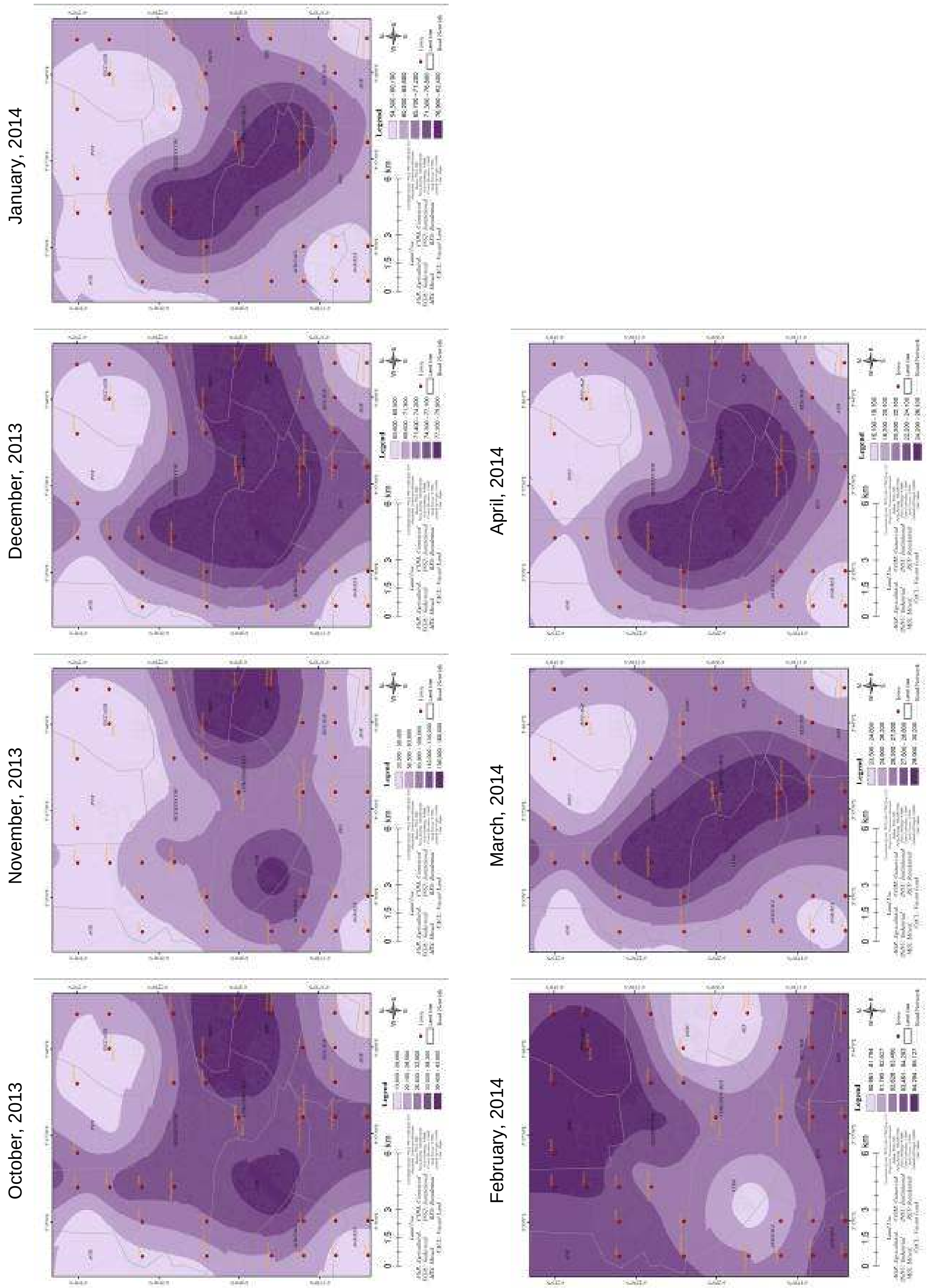


**Fig. 3. Spatial and temporal variations in concentration values of pm0.5µm**

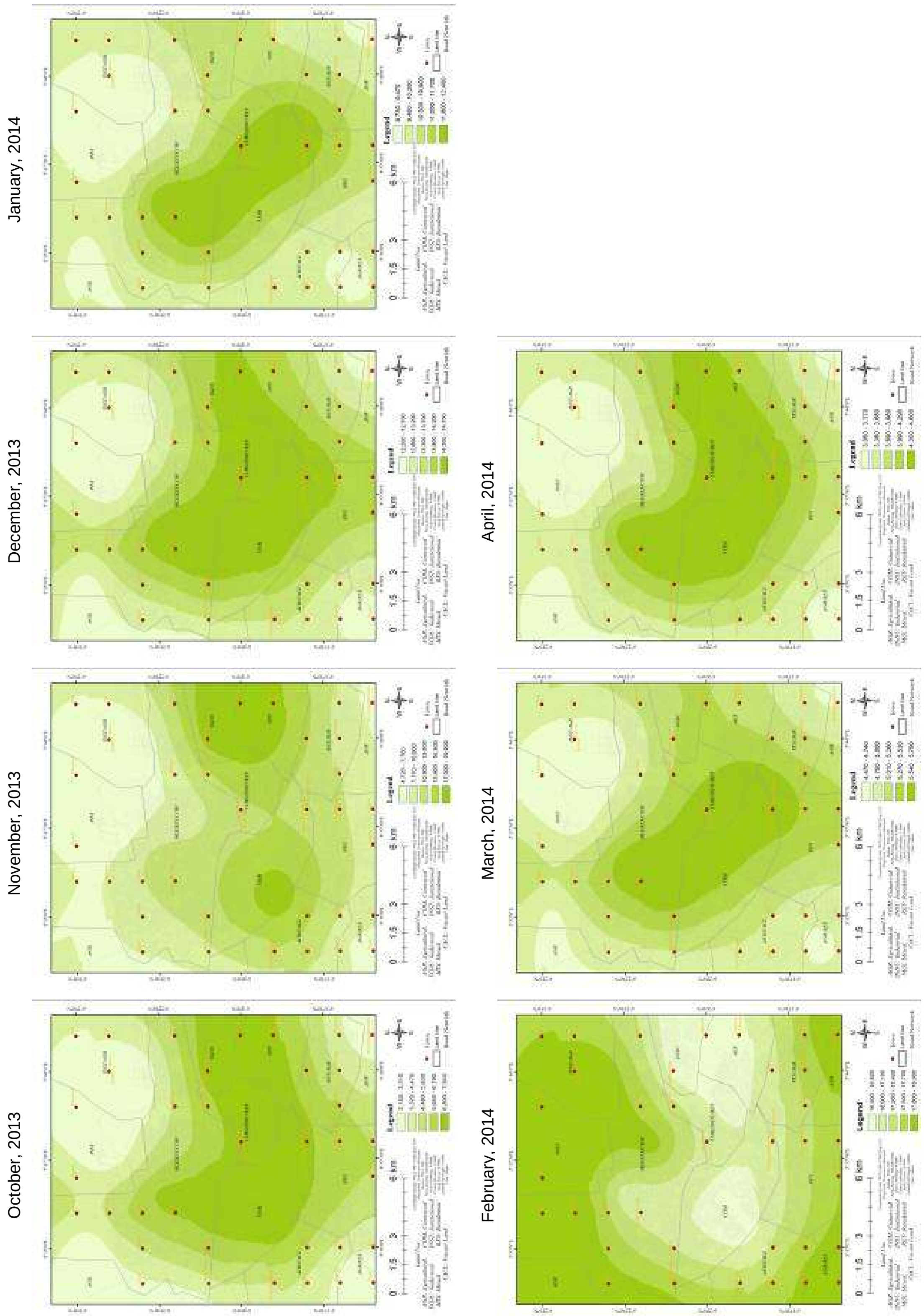


**Fig. 4. Spatial and temporal variations in concentration values of PM1.0µm**

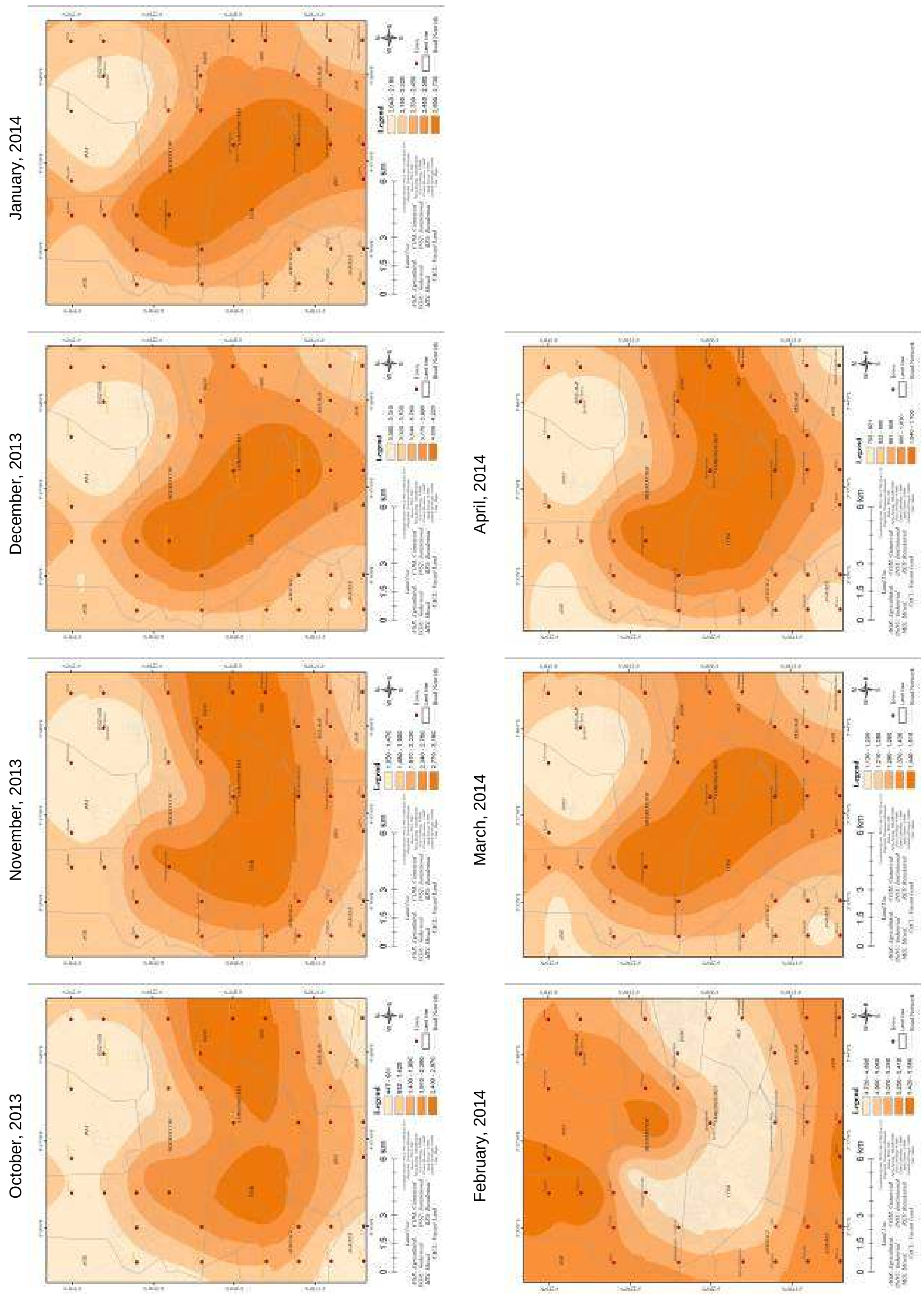


**Fig. 5. Spatial and temporal variations in concentration values of PM2.5μm**

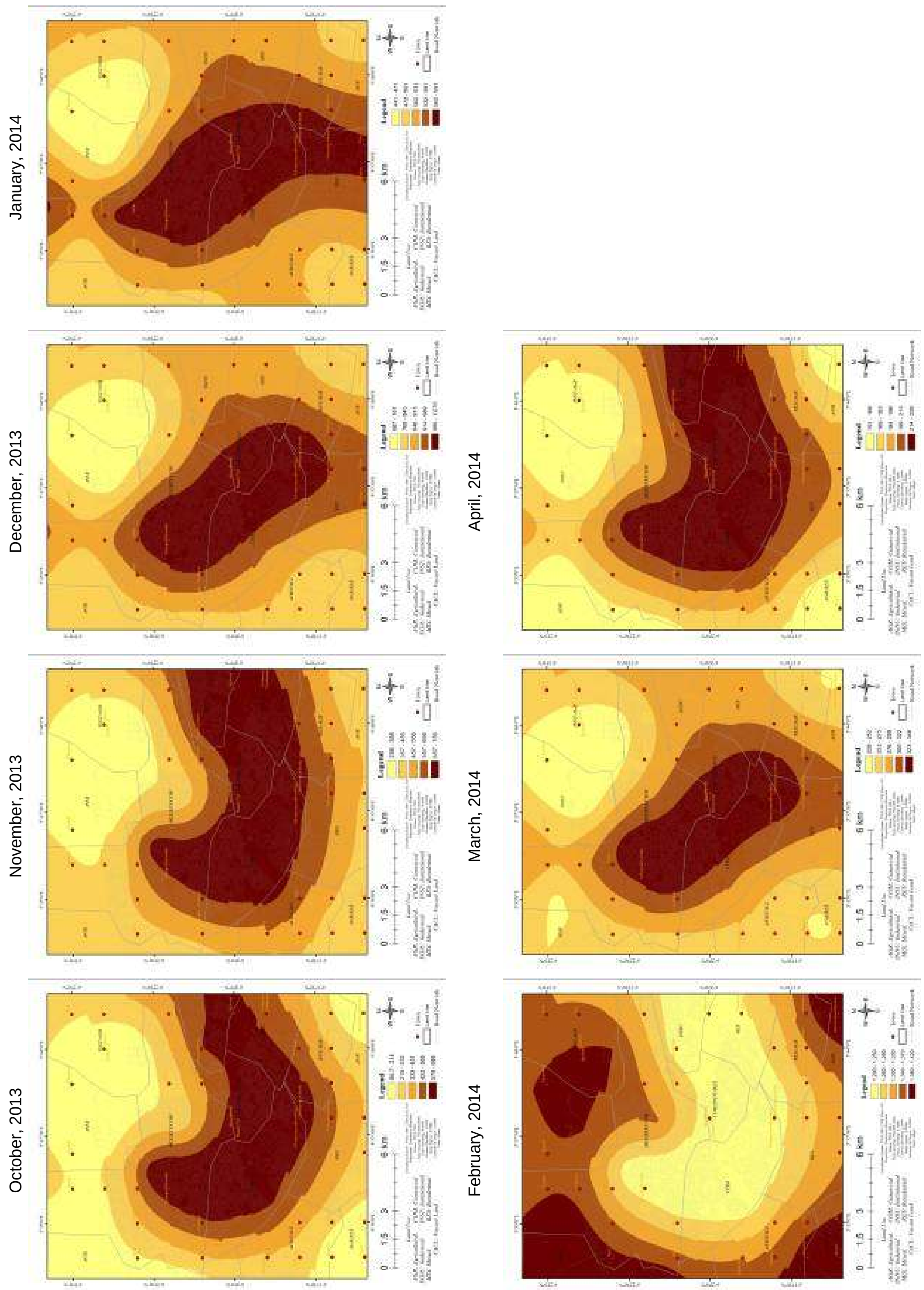


**Fig. 6. Spatial and temporal variations in concentration values of PM5.0μm**

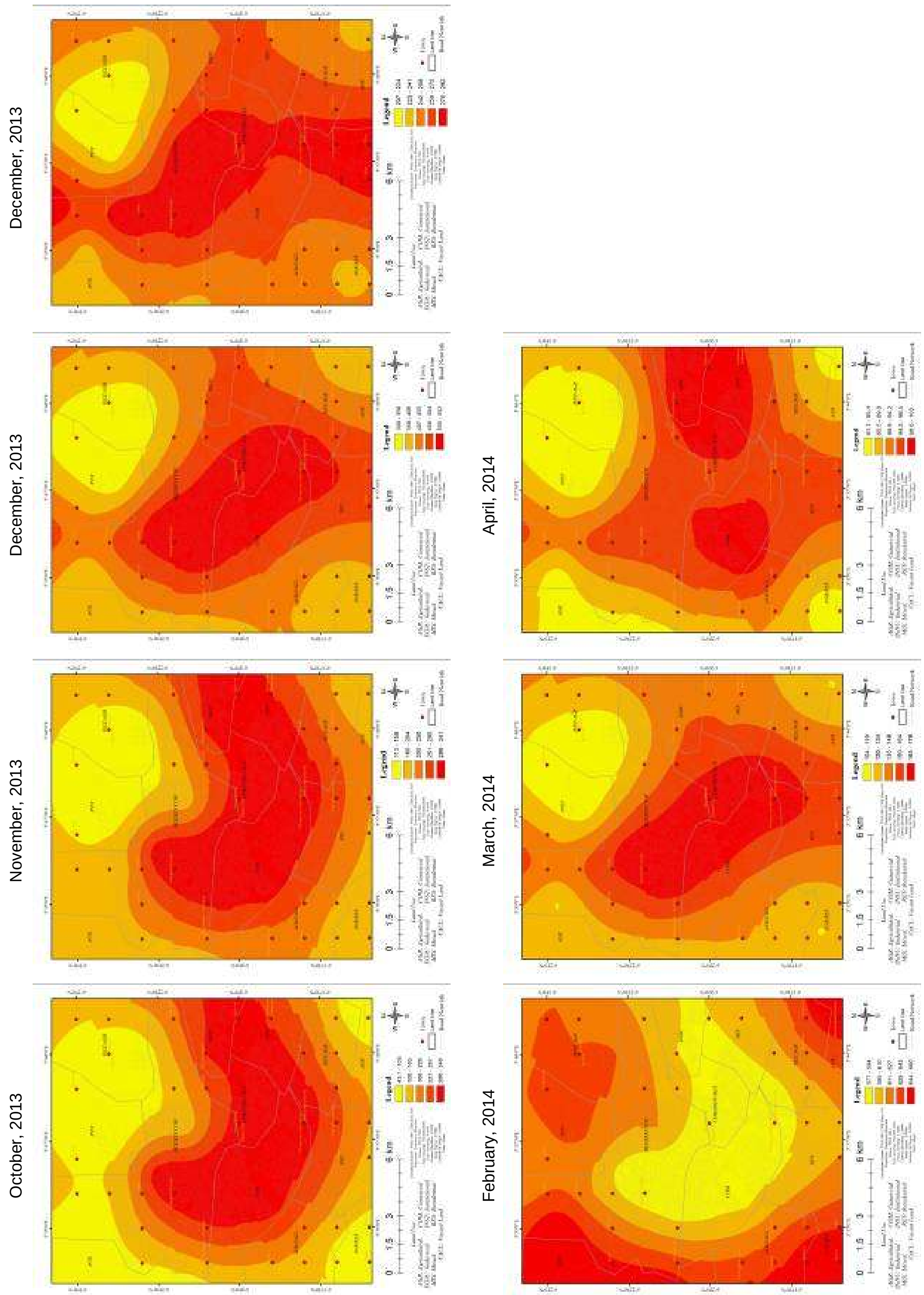


**Fig. 7. Spatial and temporal variations in concentration values of PM10.0µm**

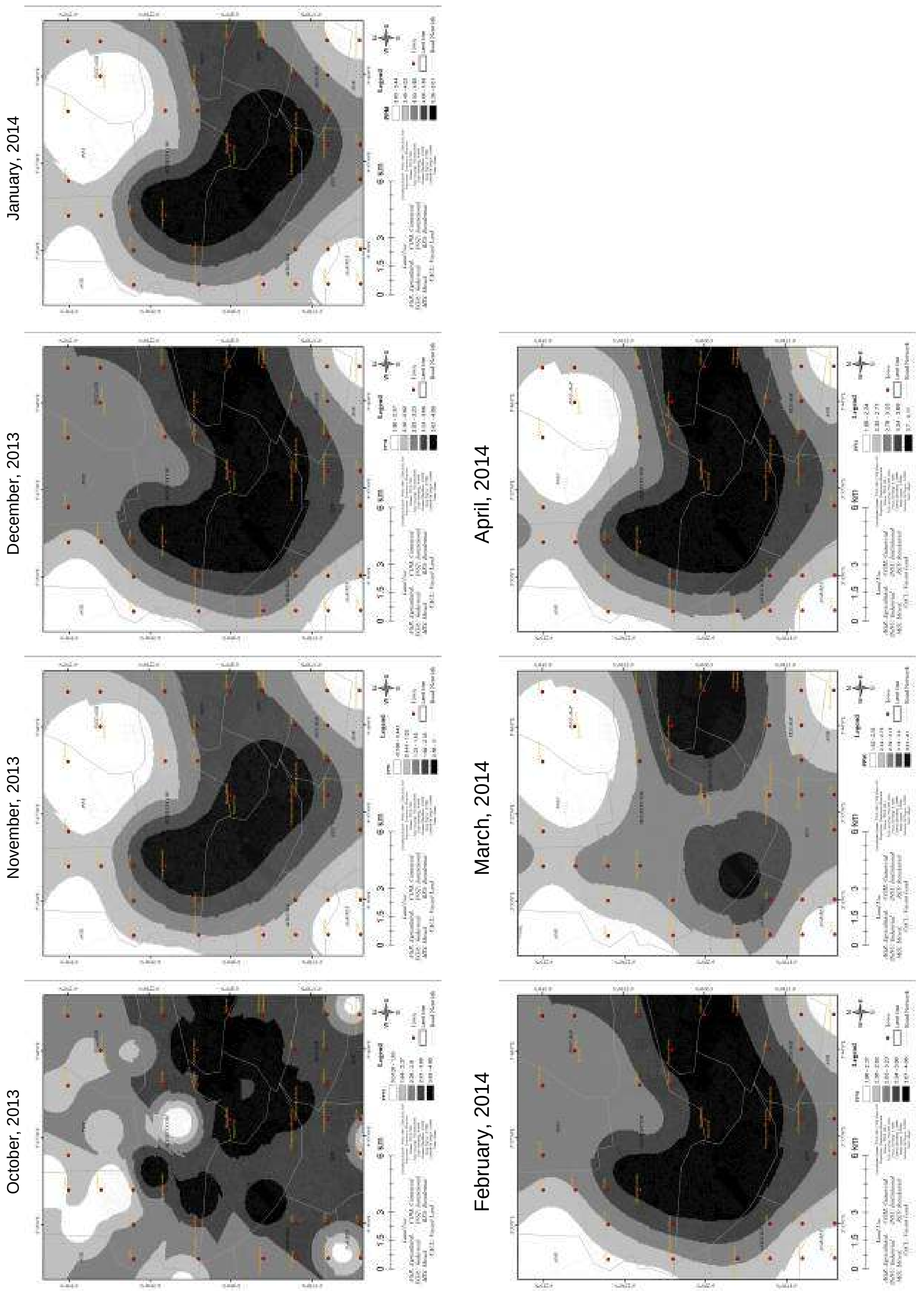


**Fig. 8. Spatial and temporal variations in concentration values of co (PPM)**

**Table 2. Total mean values of air pollutant concentration for different land uses**

| Sampling location | Concentration of particle counts and co per 0.1ft³ of sampled air | | | | | | |
|---|---|---|---|---|---|---|---|
| | $PM_{0.3µm}$ | $PM_{0.5µm}$ | $PM_{1.0µm}$ | $PM_{2.5m}$ | $PM_{5.0m}$ | $PM_{10µm}$ | CO(PPM) |
| 1. University of Benin (UNIBEN) | 184 741 | 47 104 | 8 347 | 2 131 | 497 | 230 | 2.08 |
| 2. PPRH Plantation | 183 210 | 48 040 | 8 722 | 2 254 | 531 | 252 | 1.81 |
| 3. Ring road/ Mission road. | 259 558 | 65 676 | 11 291 | 2 891 | 704 | 345 | 4.23 |
| 4. Ikpoba Hill/ Benin-Auchi road | 263 770 | 72 380 | 11 668 | 2 800 | 652 | 317 | 3.96 |
| 5. Akugbe/ Eweka road. | 218 432 | 55 472 | 9 788 | 2 546 | 597 | 296 | 2.75 |

Table 3 describes 9 classes of environments ranging from class 1 (representing the cleaner class) to class 9, (representing the dirtier class). By comparing them with mean values derived from the field in Table 4, we notice that all land use types in the study area fall into the categories of the dirtier classes 6, 8 and 9. Previous study carried out by Ukpebor et al. at five commercial sites in Benin City reveal concentration values of Total Suspended Particulates (TSP) ranging from 240 $µgm^{-3}$ to 675 $µgm^{-3}$ [5]. This present study, using particle counts further buttresses the fact that commercial areas are recipients of the highest concentration values of pollutants in the city. Particulate matter emission from air polluting land use activities (such as commercial and industrial land uses) have been known to cause various health and environmental problems. Human exposure to air pollution has been linked to a number of different health effects, ranging from modest transient changes in the respiratory tract, impaired pulmonary function, to restricted activity or reduced performance, emergency room visits, hospital admissions and to mortality.

There is increasing evidence on adverse effects of particulates on the respiratory system, as well as the cardiovascular system. This evidence emerges from studies on acute and chronic exposures [1].

For Carbon Monoxide having mean concentration values ranging from 1.7ppm to 4.1ppm, the regulatory limit of 90 ppm for 15 minutes was not exceeded. Yet one should be aware that though regulatory limits are based on effective thresholds below which significant health impacts are not likely to occur, there might be no absolute guarantee for such, especially for the fragile population, such as the children, the elderly and those with serious respiratory challenges. It is worth pointing out that previous study done in Benin City by Ukpebor et al. using a hand held docimeter, revealed mean concentration values of CO at all the commercial sites sampled, ranging from 15.0ppm – 28.3ppm [11]. Differences in readings between previous and present day study may be accounted for by the use of different instrumentation and sampling periods.

**Table 3. Classes of clean rooms/environments and the maximum values of particle counts per cubic meter, permissible for each class**

| Critical environment classification (ISO 14644-1) | Concentration (particles/m³) > or = Size shown | | | |
|---|---|---|---|---|
| | {Sum} $PM_{(0.1,\ 0.2\ \&\ 0.3)µm}$ | $PM_{0.5\ µm}$ | $PM_{1.0µm}$ | $PM_{5.0µm}$ |
| 1. | 12 | | | |
| 2. | 134 | 4 | | |
| 3. | 1,339 | 35 | 8 | |
| 4. | 13,390 | 352 | 8 | |
| 5. | 133,900 | 3,520 | 832 | 29 |
| 6. | 1,339,000 | 35,200 | 8,320 | 293 |
| 7. | | 352,000 | 83,200 | 2,930 |
| 8. | | 3,520,000 | 832,000 | 29,300 |
| 9. | | 35,200,000 | 8,320,000 | 293,000 |

*Source: [18]*

**Table 4. Particle counts per 1m$^3$ (35.315ft$^3$) of air volume sampled**

| Sampling location | Particle counts per 1m$^3$ (35.315ft$^3$) of air volume sampled | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{0.3\ \mu m}$ | $PM_{0.5\ \mu m}$ | $PM_{1.0\ \mu m}$ | $PM_{2.5\ \mu m}$ | $PM_{5.0\ \mu m}$ | $PM_{10\ \mu m}$ |
| 1. University of Benin (UNIBEN) | 65 241 284 | 16 634 778 | 2 947 743 | 752 563 | 175 516 | 81 225 |
| Environmental class | 8 | 6 | 6 | - | 9 | - |
| 2. PPRH plantation | 64 700 612 | 16 965 326 | 3 080 174 | 796 000 | 187 523 | 88 994 |
| Environmental class | 8 | 6 | 6 | - | 9 | - |
| 3. Ring road/ Mission road. | 91 662 908 | 23 193 479 | 3 987 417 | 1 020 957 | 248 618 | 121 837 |
| Environmental class | 8 | 6 | 6 | - | 9 | - |
| 4. Ikpoba Hill/ Benin-Auchi road | 93 150 376 | 25 560 997 | 4 120 554 | 988 820 | 230 254 | 111 949 |
| Environmental class | 8 | 6 | 6 | - | 9 | - |
| 5. Akugbe/ Eweka road. | 77 139 261 | 19 589 937 | 3 456 632 | 899 120 | 210 831 | 104 532 |
| Environmental class | 8 | 6 | 6 | - | 9 | - |

*Source: Field work, Benin City (2014)*

Note that 1m$^3$ of sampled air = 35.315ft$^3$ of sampled air

Therefore deriving mean values of particle counts for 35.315ft$^3$ of air from 0.1ft$^3$ of sampled air is calculated as;

$$\text{Particle count per } 35.315\text{ft}^3 \text{ of pumped air} = \frac{\text{particle count per } 0.1\text{ft}^3 \text{ of air pumped} \times 35.315}{0.1}$$

### 3.1 Implication of the Study

Protecting citizens of a community, especially children from the health effects of air pollution is one of the most fundamental goals of environmental health researches and programs. Air pollution in cities could occur naturally, but it is in most case, man-induced. This is the reason for the need to emphasize the connection between air quality and human activities. Because the siting process of land use activities which could cause air pollution involves permitting by Ministries of Lands, Housing and Urban Development, it therefore implies the importance for coordination between air quality research institutes/programs and town planning authorities. Policies should be implemented, such that would inhibit adjacent placement of incompatible land uses, barricade high polluting land uses using buffer zones, execute proper zoning systems and establish of strategically located motor parks. Benin City is highly deficient in land allocated to commercial motor parks. As such, ply routes are continually used by commercial drivers in boarding passengers. This has led to stalling of traffic on roads, leading further to higher accumulation of pollutants within any vicinity.

## 4. CONCLUSION

The results from both statistical analysis and GIS showed higher concentration of pollutants in commercial and industrial land use types, moderate concentrations in residential land use, and lower concentrations in institutional and agricultural land use types. The factors which could account for these differences include differences in;

- density of human and vehicular traffic
- rate of traffic flow
- nature of the land surface; vegetated, earth, concrete or tarred surfaces
- presence of combustion processes, such as burning/incineration, operation of diesel engines and power generating and industrial plants
- meteorological conditions.

Some of these factors are more prominent in industrial and commercial land use types. Commercial areas with regular traffic jams are mostly affected. High traffic density and inhibited traffic flow imply that stalled vehicles emit more pollutants for a longer period at the same location. Urgent measures carried out by Town Planning authorizes, such as  are required at these commercial areas, because they are places daily visited by a large number of people, who are invariably exposed to high CO and Particulate Matter dosage, with its attendant health impacts. For residential land use type, the factors listed above are either moderate or non-existent. The factors that could account for high CO and PM concentration in residential areas include non-tarred surfaces, solid waste burning and running of privately owned electricity generating sets. For institutional and agricultural land use types, these factors are either minimal or totally non-existent.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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